Improving the Fermilab Booster Notchning Efficiency: Beam Losses and Radiation Levels

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Outline

- Problem: Distributed beam losses in Booster beam line. Elevated radiation levels.
- Goal: Investigate variants to improve beam notching efficency, decrease radiation levels (ALARA) in tunnel.
- Approach: Modification of kickers in section 5 or section 12 to localize beam losses in dedicated regions with appropriate shielding.
- Tools: Simulations with MARS and STRUCT codes.
- Results: Energy deposition in beam dump used in notchning, residual doses and star density in sump water around tunnel.
- Conclusion

Present situation:

- Present situation: fast 1.08-m long kicker (notcher) located in Booster Long-5 straight section is used to remove 3 of 84 circulating bunches after pulse injection to generate abort gap.
- With magnetic field 72.5 Gauss kicker removes 87% of the 3-bunch intensity at 400 MeV:
  - 75% on pole tips of the focusing Booster magnets
  - 11% on the Long-6 collimators
  - 1% in the rest of ring

  Problems :
- Elevated dose level in booster tower
- High residual doses on magnets and tunnel walls.

Radiation Limits and Design Constraints

- Residual dose rate on contact with materials inside tunnel

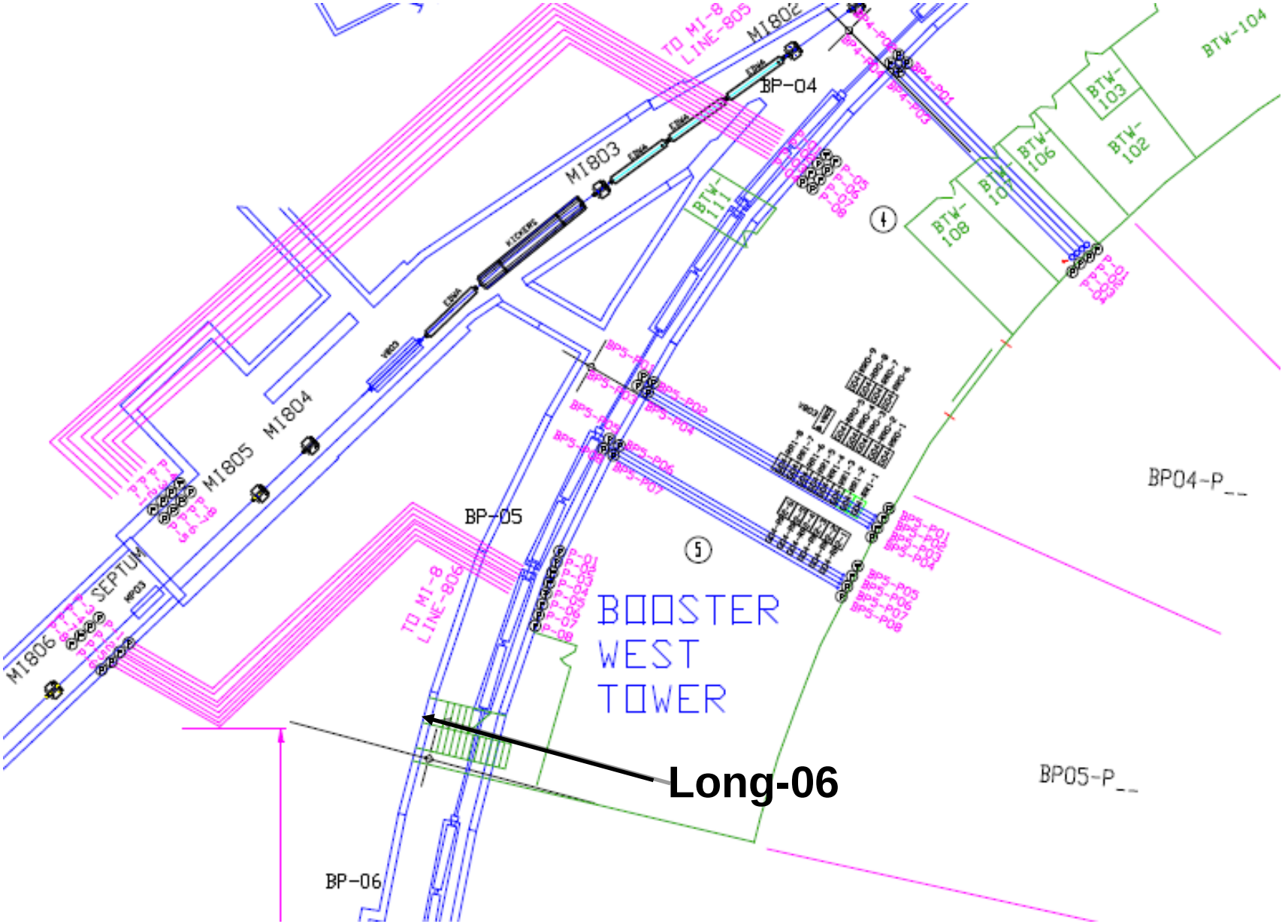
$$P_{\gamma} < 100\, mrem/h = 1\, mSv/h$$

- Sump water activation:

$$\langle S \rangle_{gravel} < 4000\, cm^{-3}\, s^{-1}$$

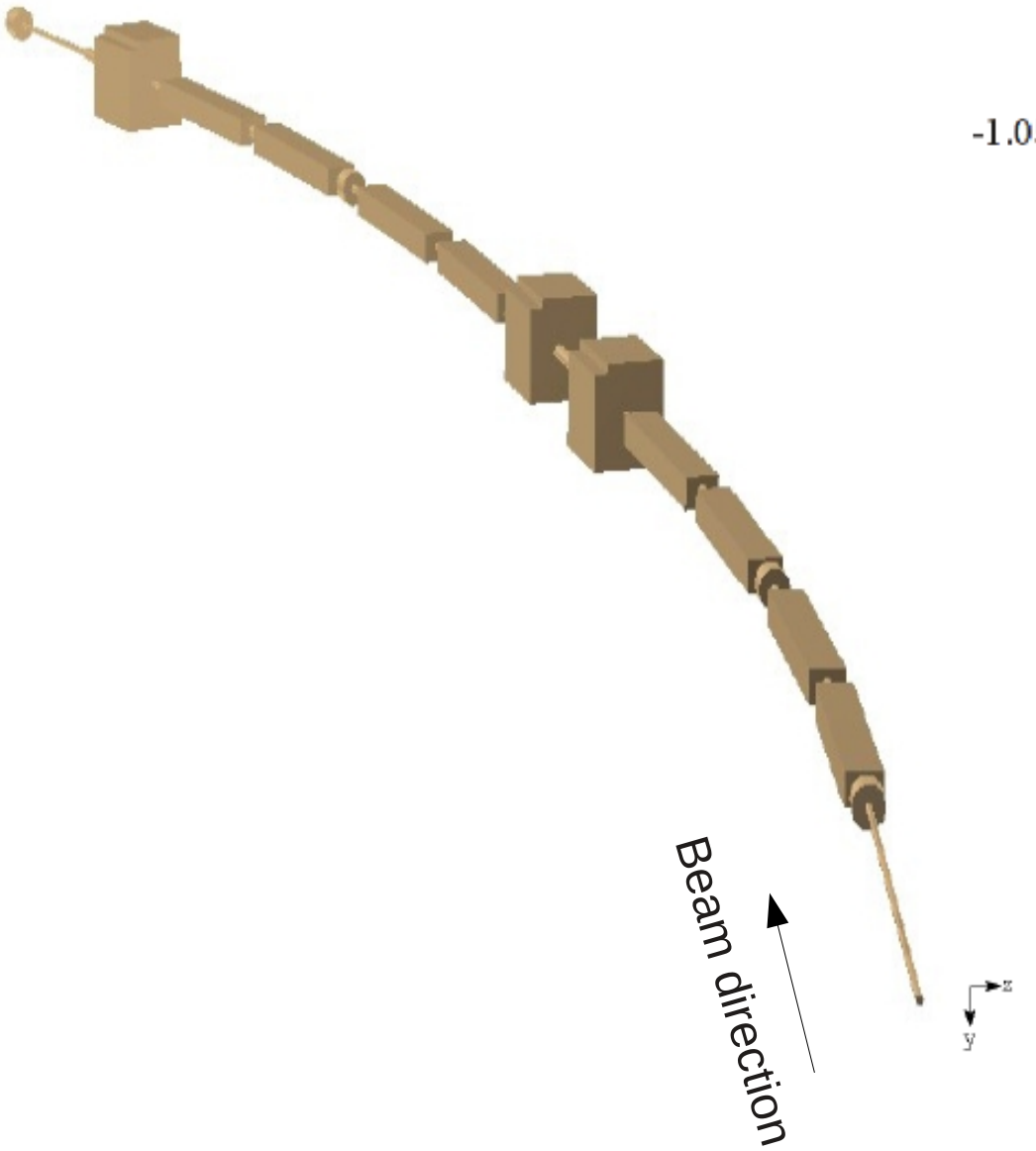
- Prompt dose equivalent above tunnel, 13.5 feet of dirt:

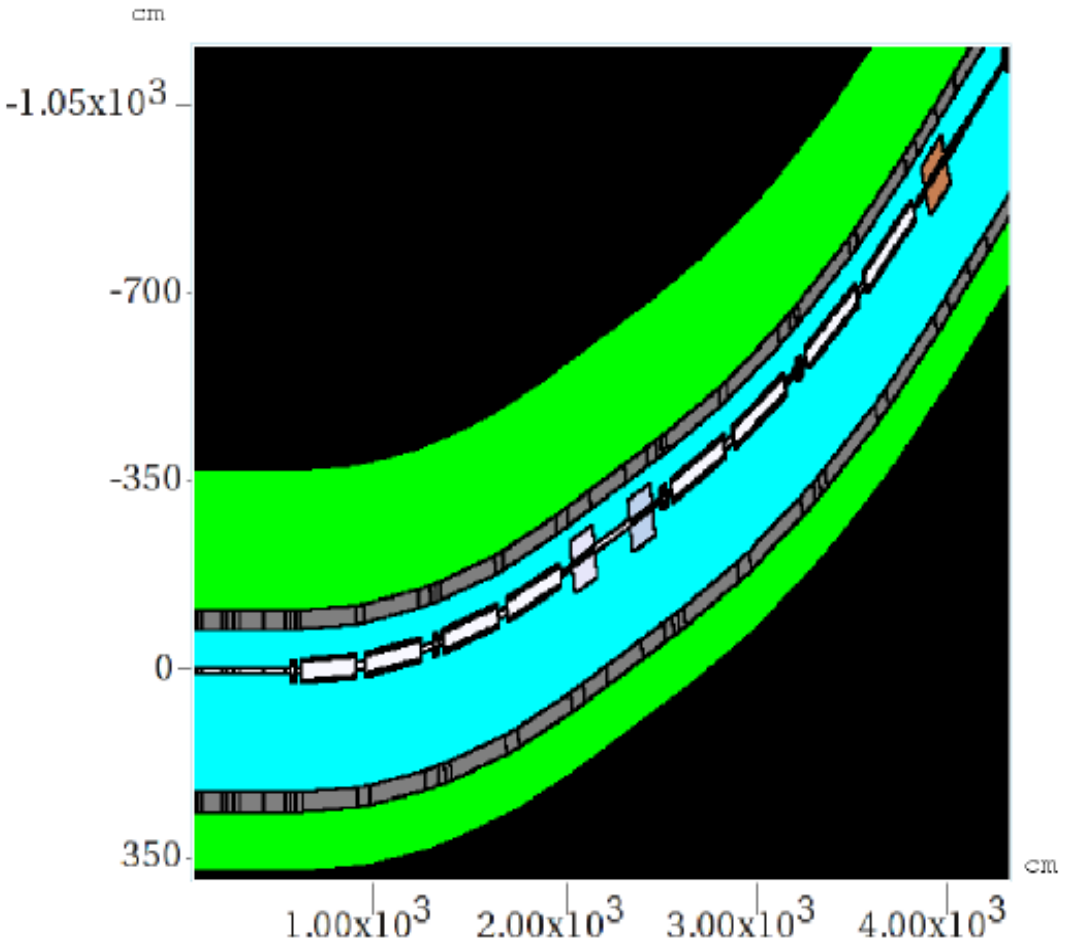
$$D_E < 5\,\frac{mrem}{h} = 0.05\,\frac{mSv}{h}$$



The Booster west tower starts in the center of Long-06.

MARS-15 model: Booster-06 and -07 sections. Booster intensity – 5.e12 ppp, repetition rate – 5Hz.





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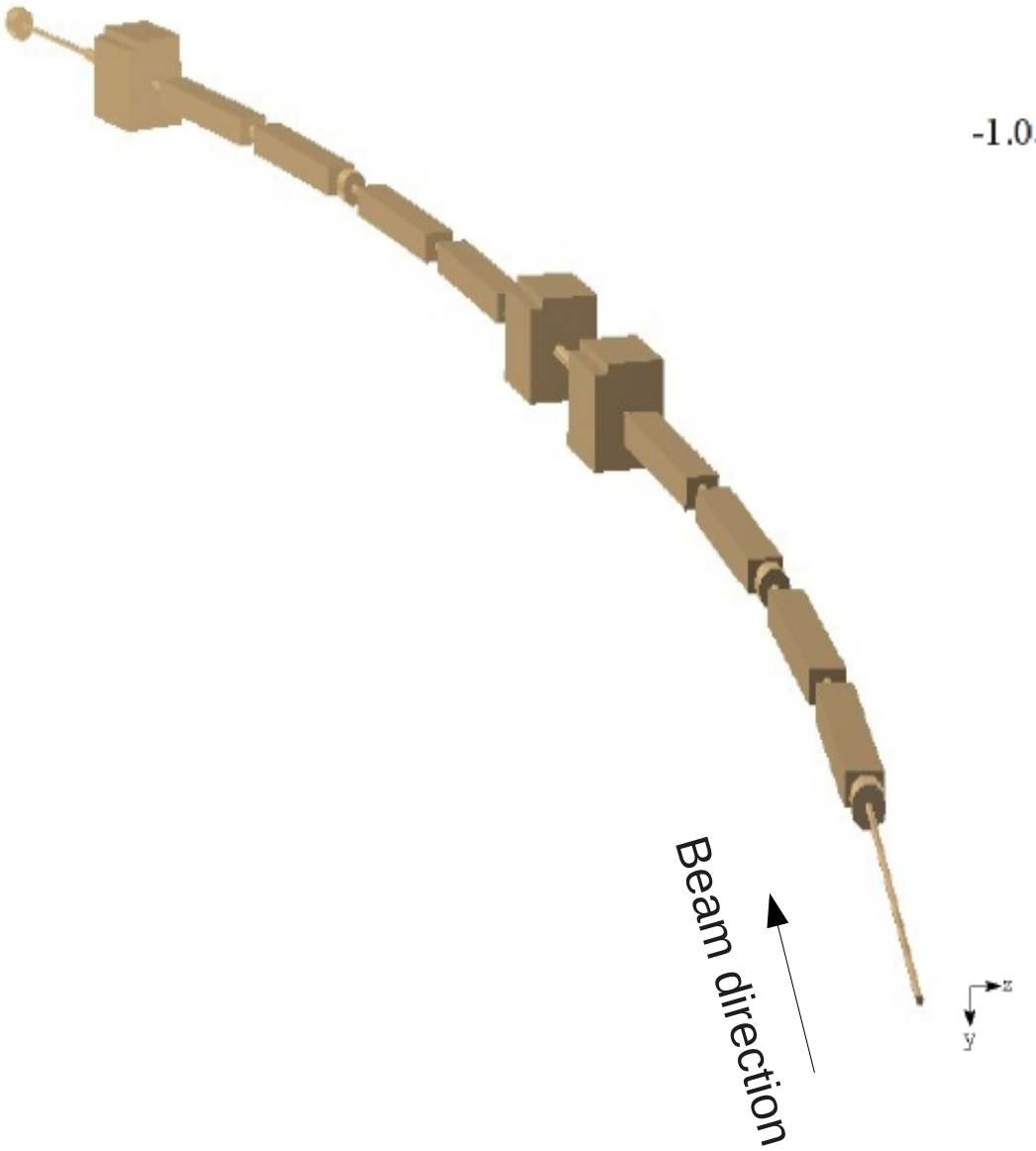
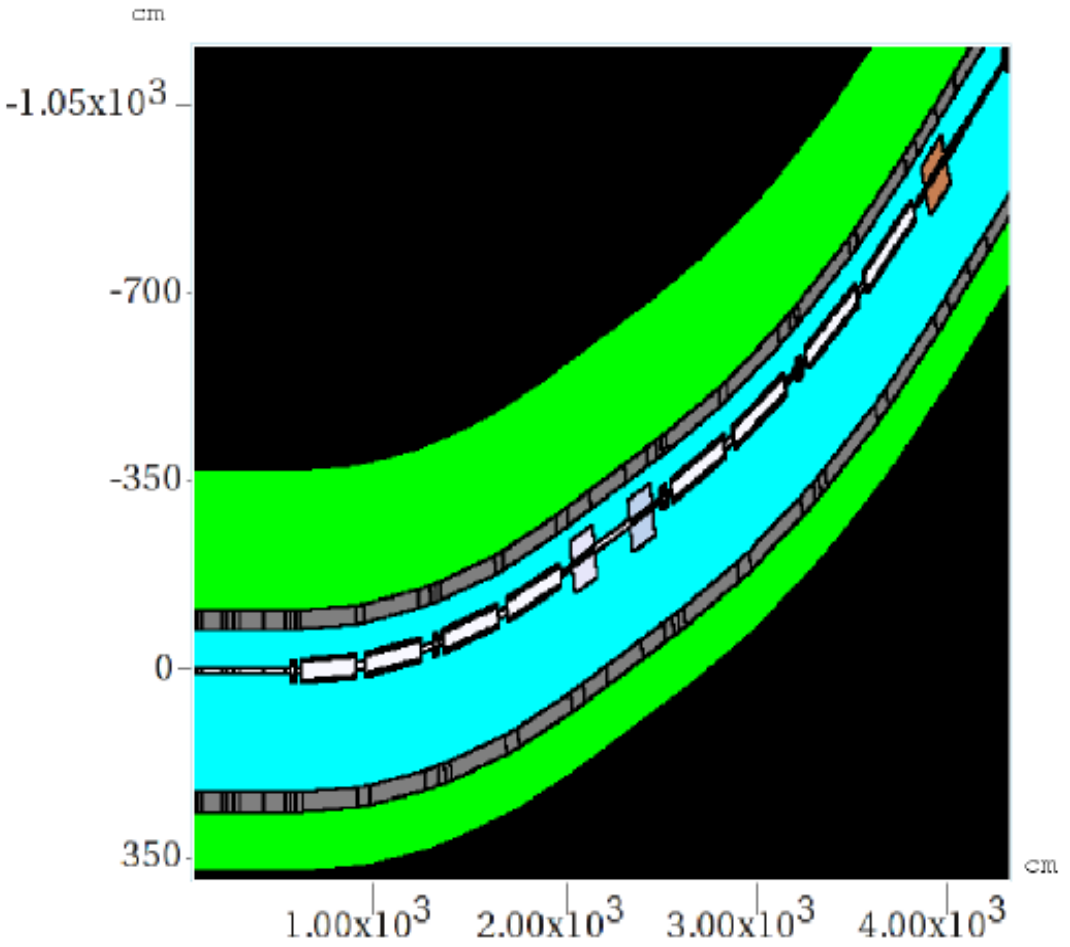
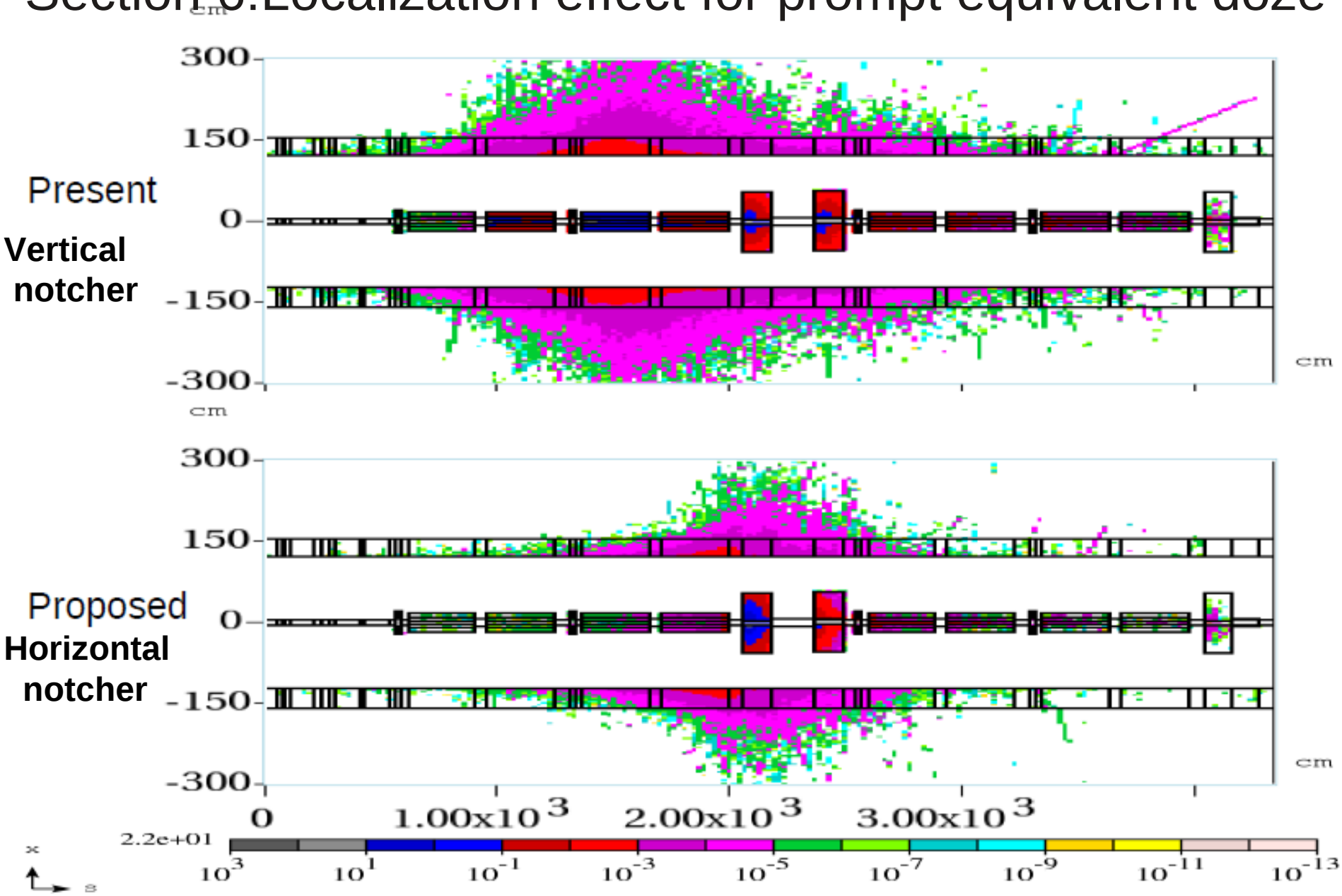


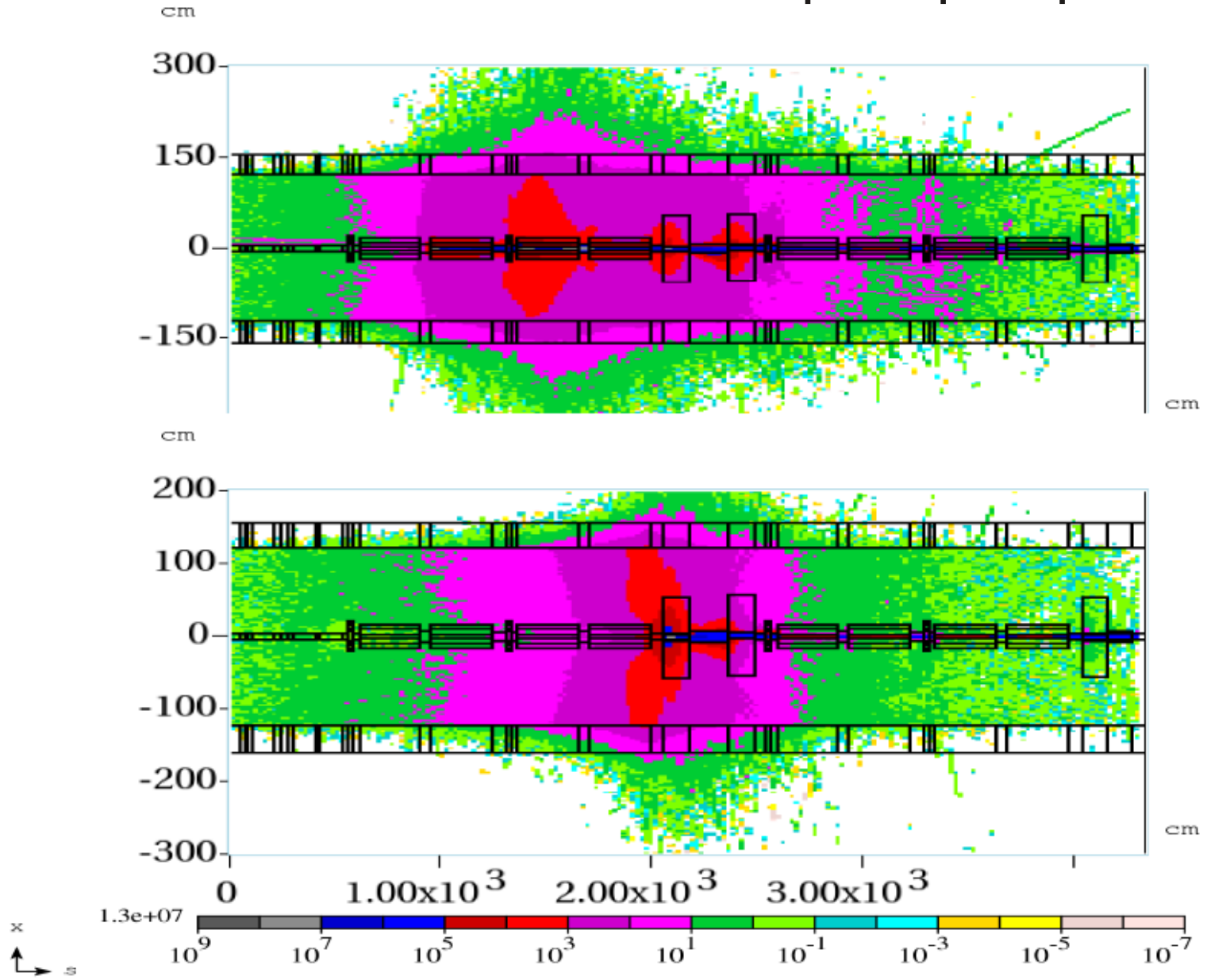


Section 6:Localization effect for prompt equivalent doze



Residual dose profiles, vertical cross section (30 days irradiation/1day cooling, mSv/hr).

Section 6:Localization effect for prompt equivalent doze

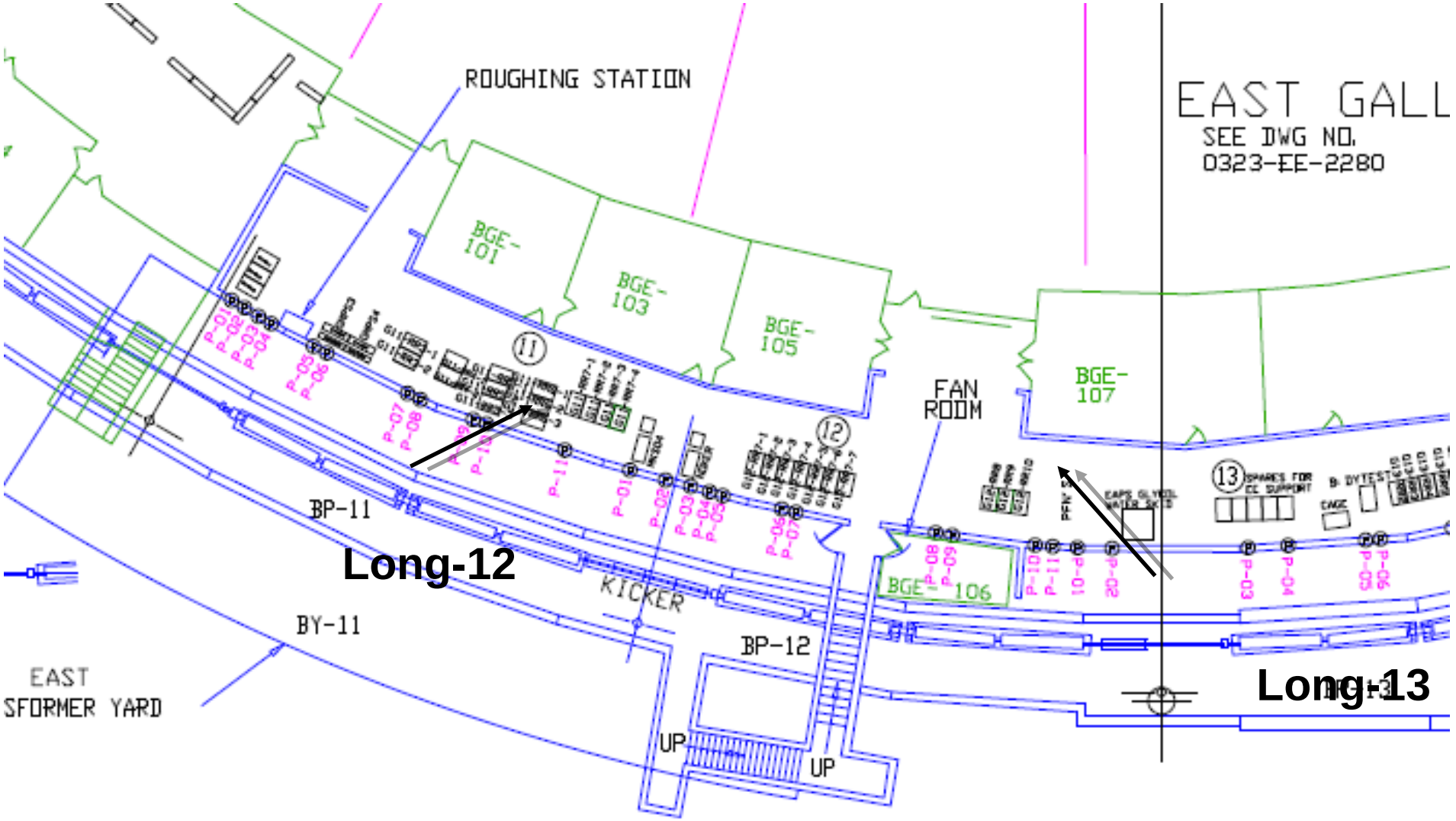


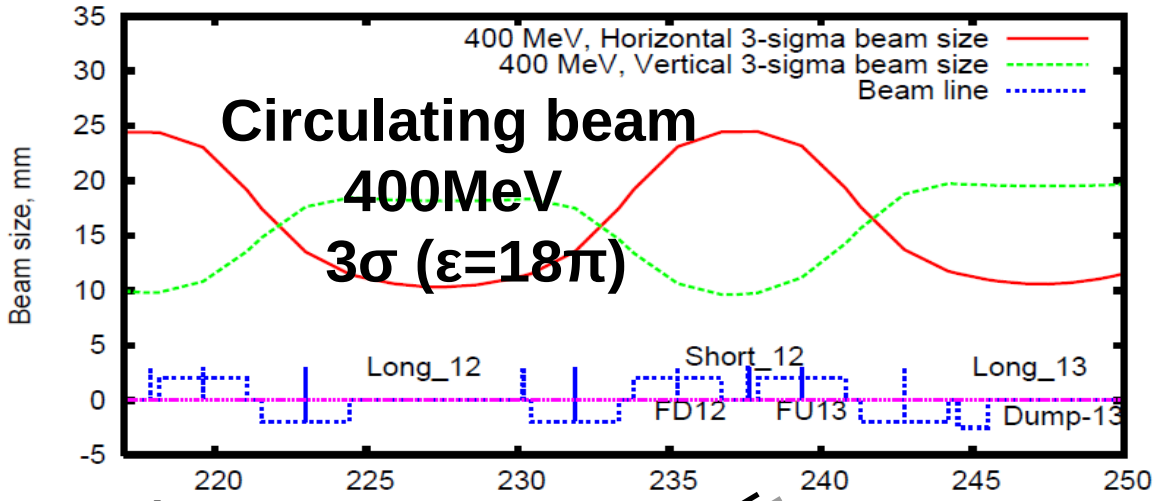
Vertical notcher

Horizontal notcher

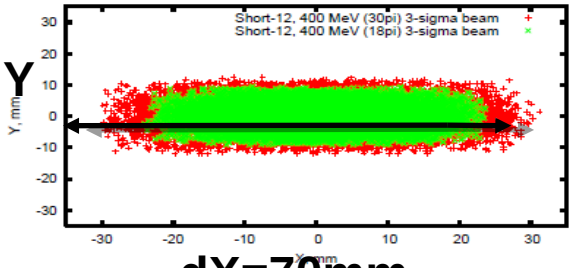
Prompt dose, vertical cross section (mSv/hr).

Layout of 12-13 sections of Booster tunnel.

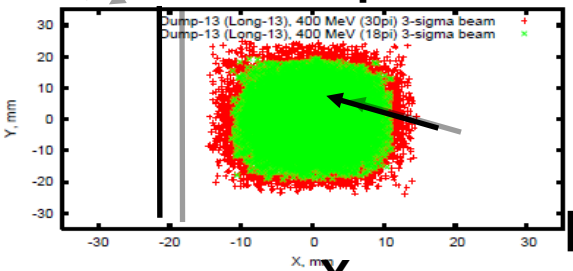




Short-12 **Dump-13**



dX=70mm



X

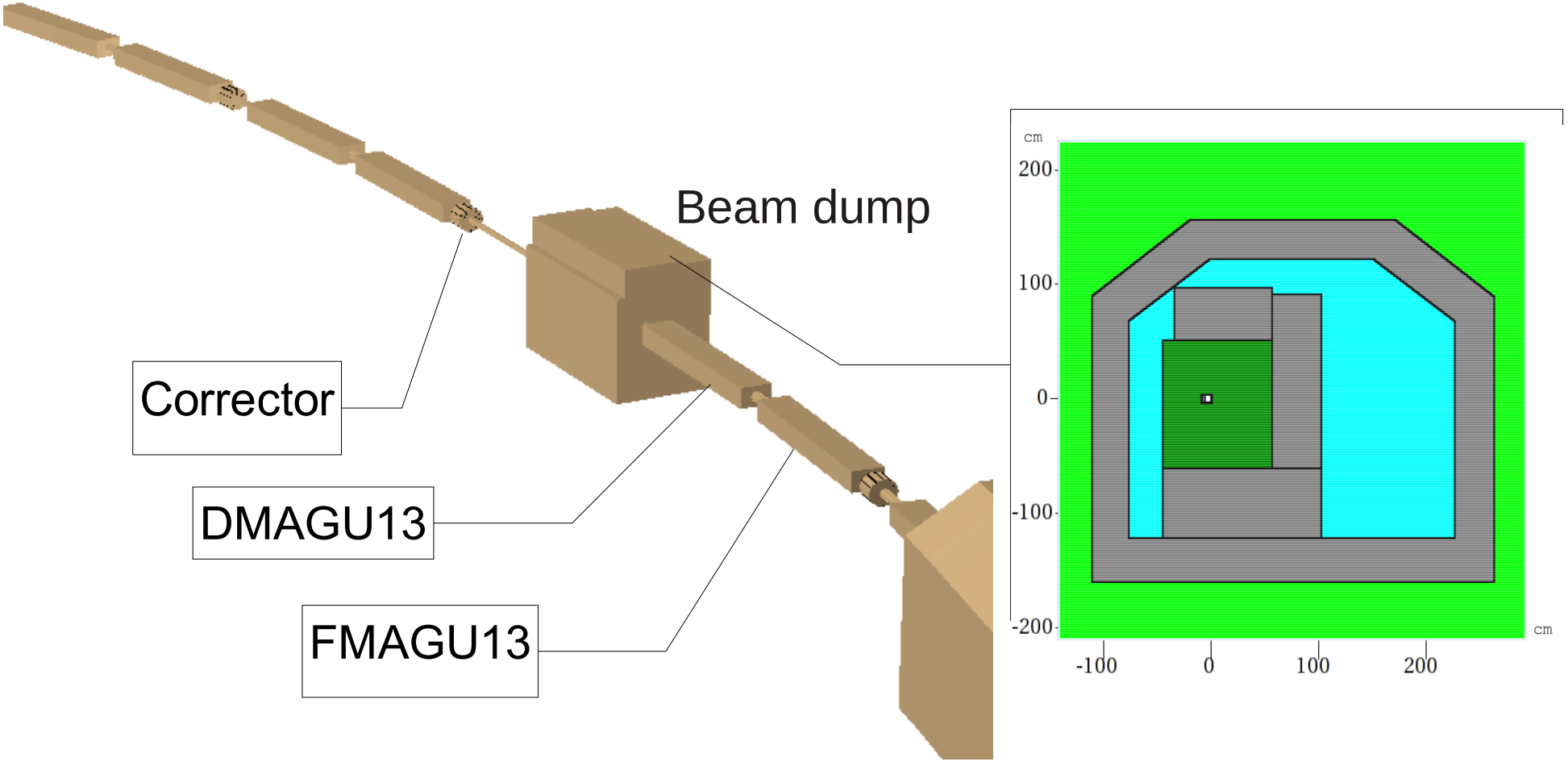
Three notchers with field of B=62 Gauss. The aperture of Short-12 straight section should be increased to R>86mm to eliminate losses. This can be done by displace-ment of R66.5mm apertu-re (without BPM) by dX=20 mm. [46.5-86.5]mm

Red – 30π, green - 18 π

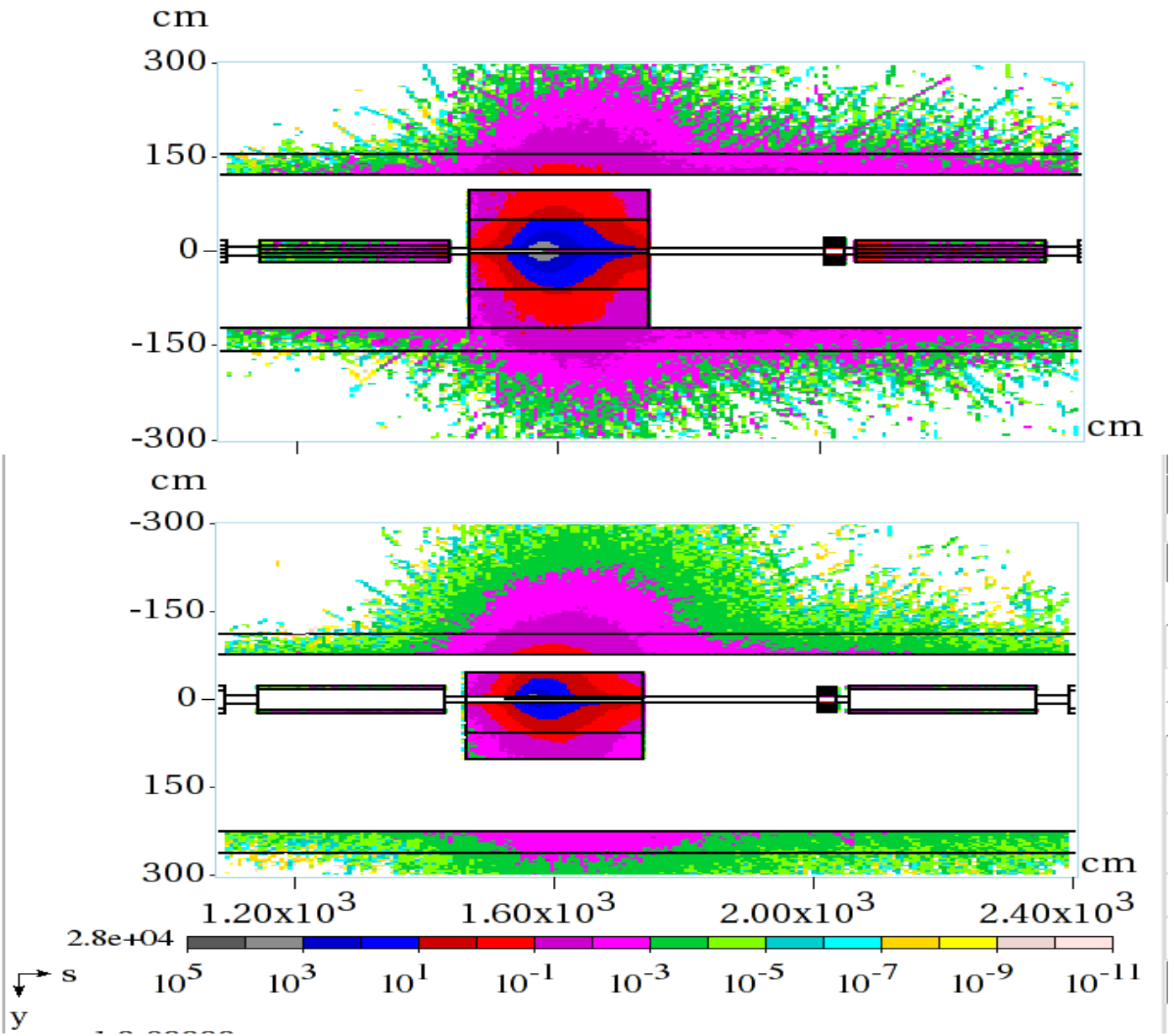
		loss from 3 bunches				loss from circulating beam		
Radius of apertur Short-12	time shift	total loss	FMAGD12, FMAGU13, DMAGU13	between FMAGD12 FMAGU13	Dump-13	total loss	between FMAGD12 FMAGU13	Dump-13
mm	nsec	%	%	%	%	%	%	%
Three long kickers with $L = 1.08m$, $E_{kin} = 400GeV$								
76.5+9.35	0	97.5	-	5.5	91.2	1.11	-	0.85
66.5+9.35	0	97.5	-	22.1	74.7	1.11	-	0.85
66.5+9.35	4	97.6	-	21.3	75.5	1.15	-	0.92
Six short kickers with $L = 0.54m$, $E_{kin} = 400GeV$								
76.5+9.35	0	98.1	-	6.4	91.0	0.24	-	0.16
66.5+19.35	0	98.1	-	5.6	90.9	0.24	-	0.22
66.5+9.35	0	98.1	-	25.8	71.7	0.24	-	0.16
66.5+9.35	4	98.2	-	23.1	74.4	0.23	-	0.21

PIP: ROOT based MARS15 model for Booster section 13:

Beam parameters: 700 MeV, Total intensity – 5.e12 ppp, repetition rate – 15Hz



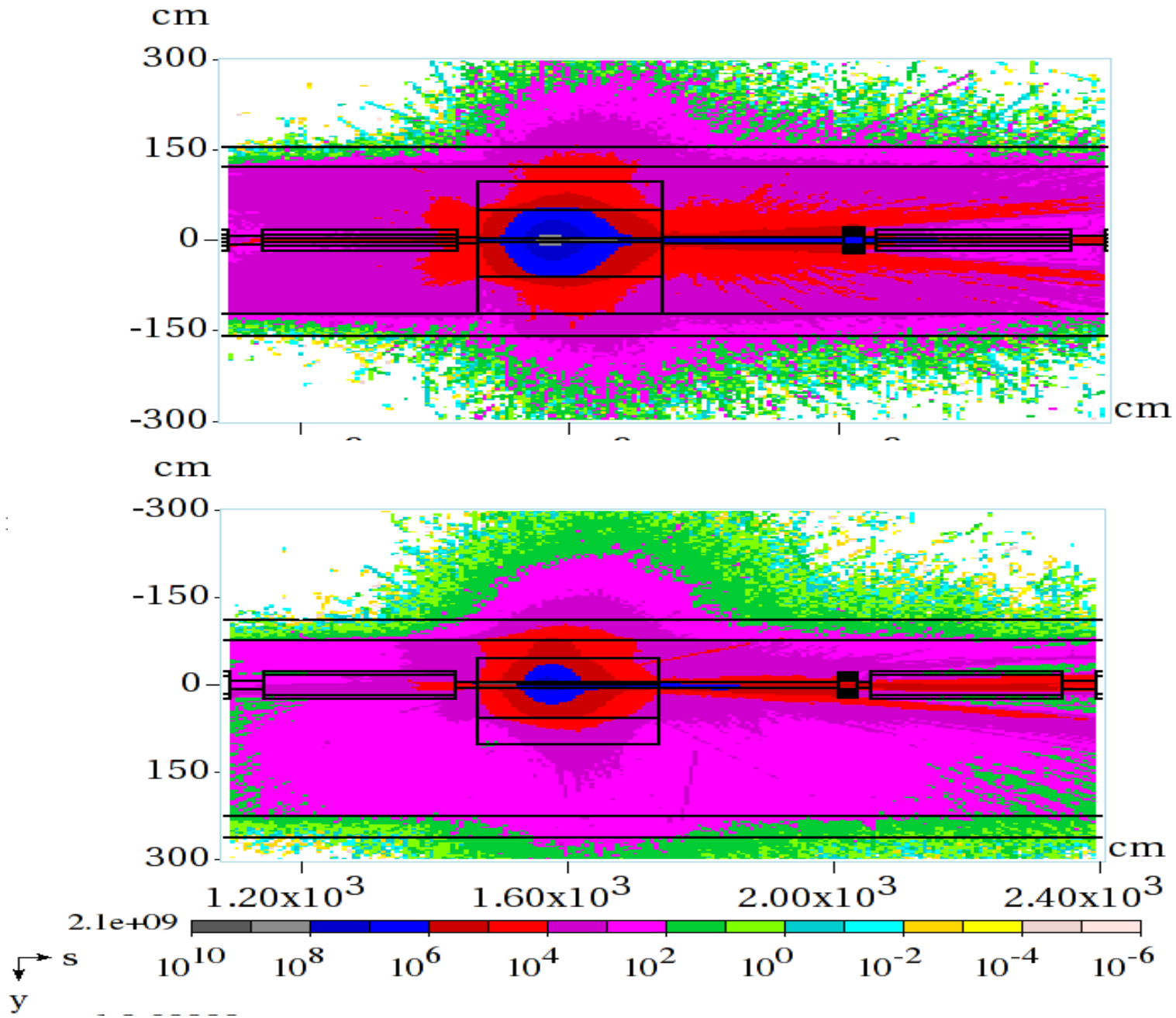
Long-13: Residual dose on contact (30d/1d) mSv/h



Side view

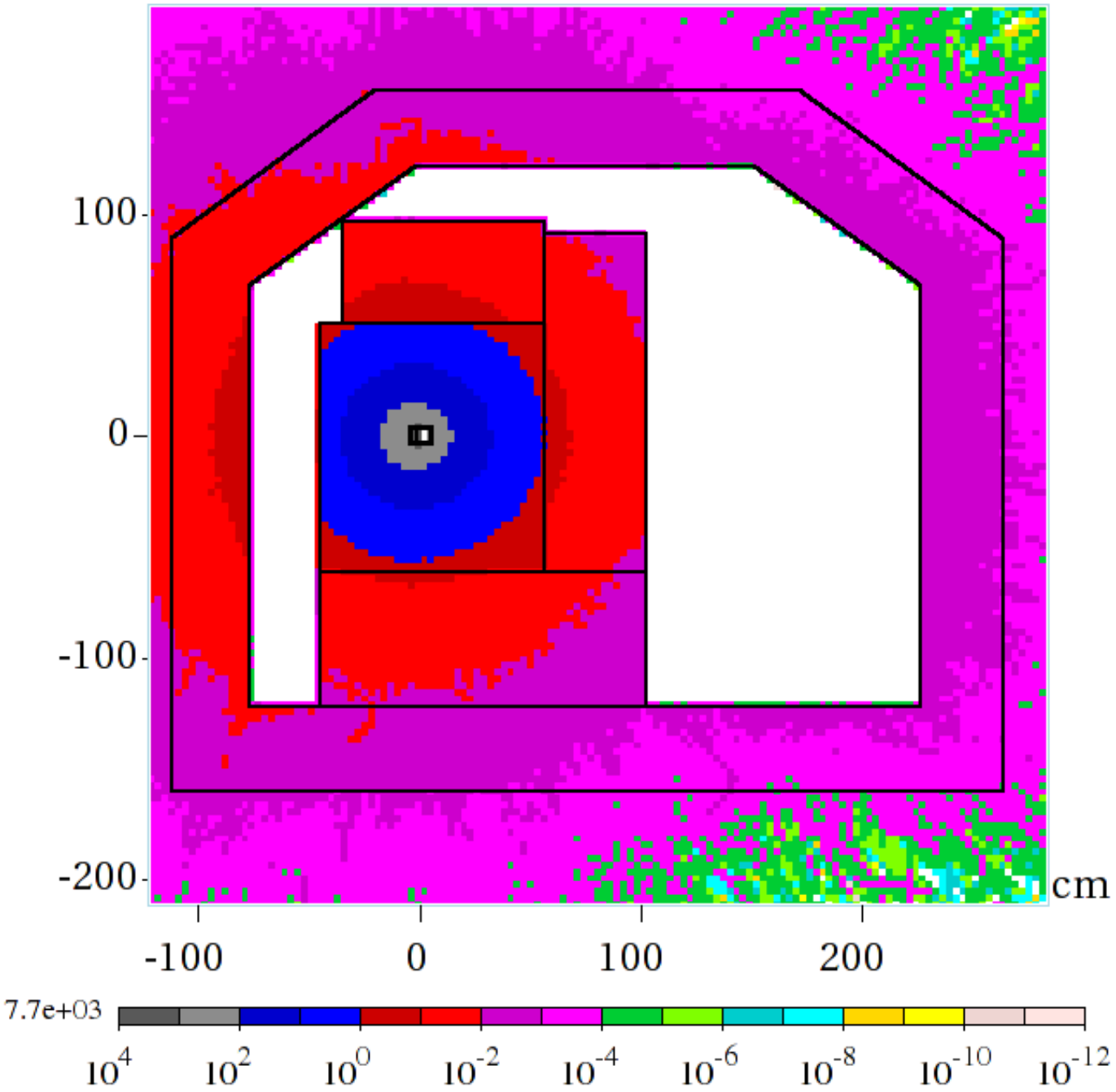
Top view

Long-13: Prompt dose equivalent, mSv/h



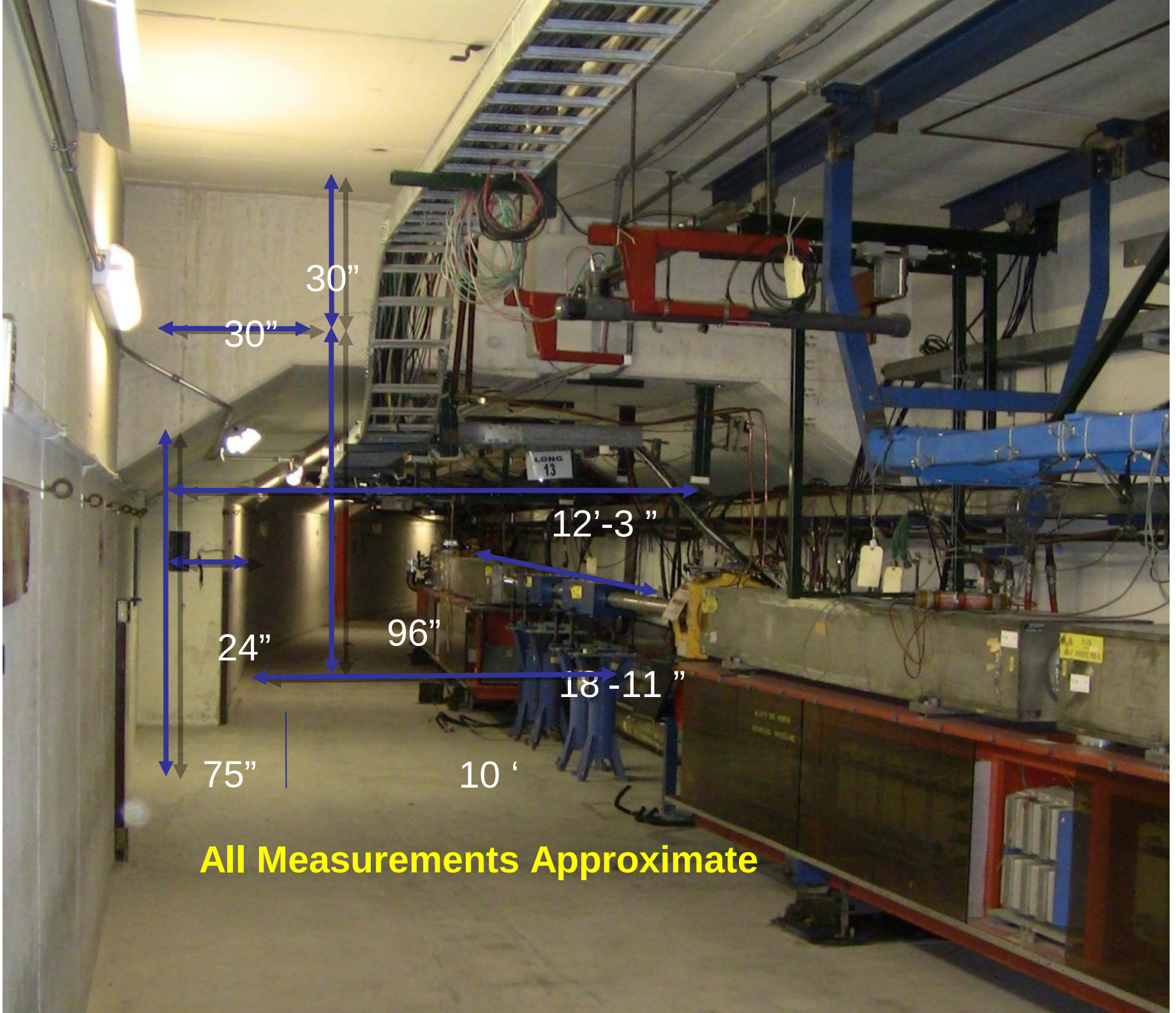
Side view

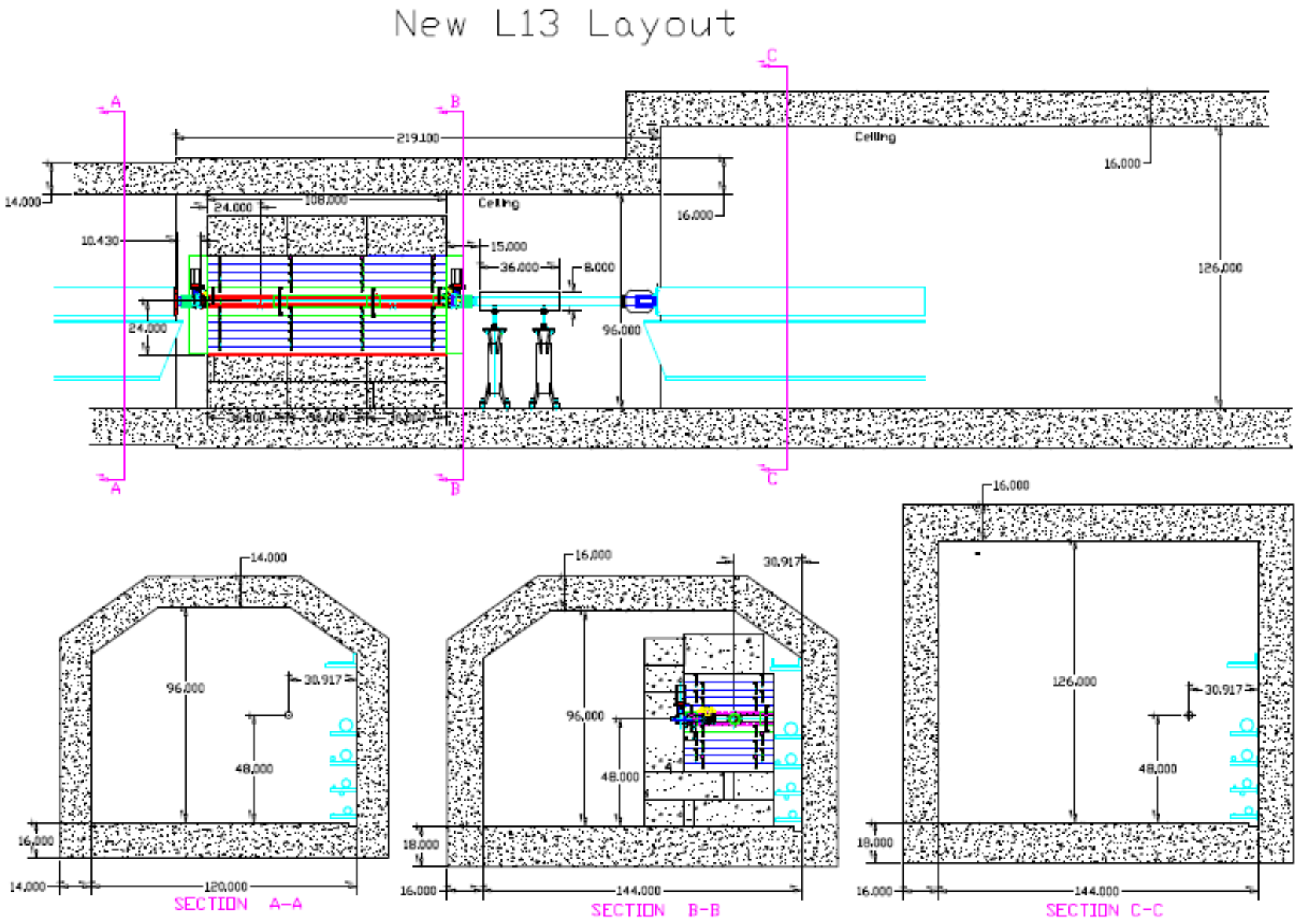
Top view



Long-13: residual dose on contact (30d/1d) mSv/h

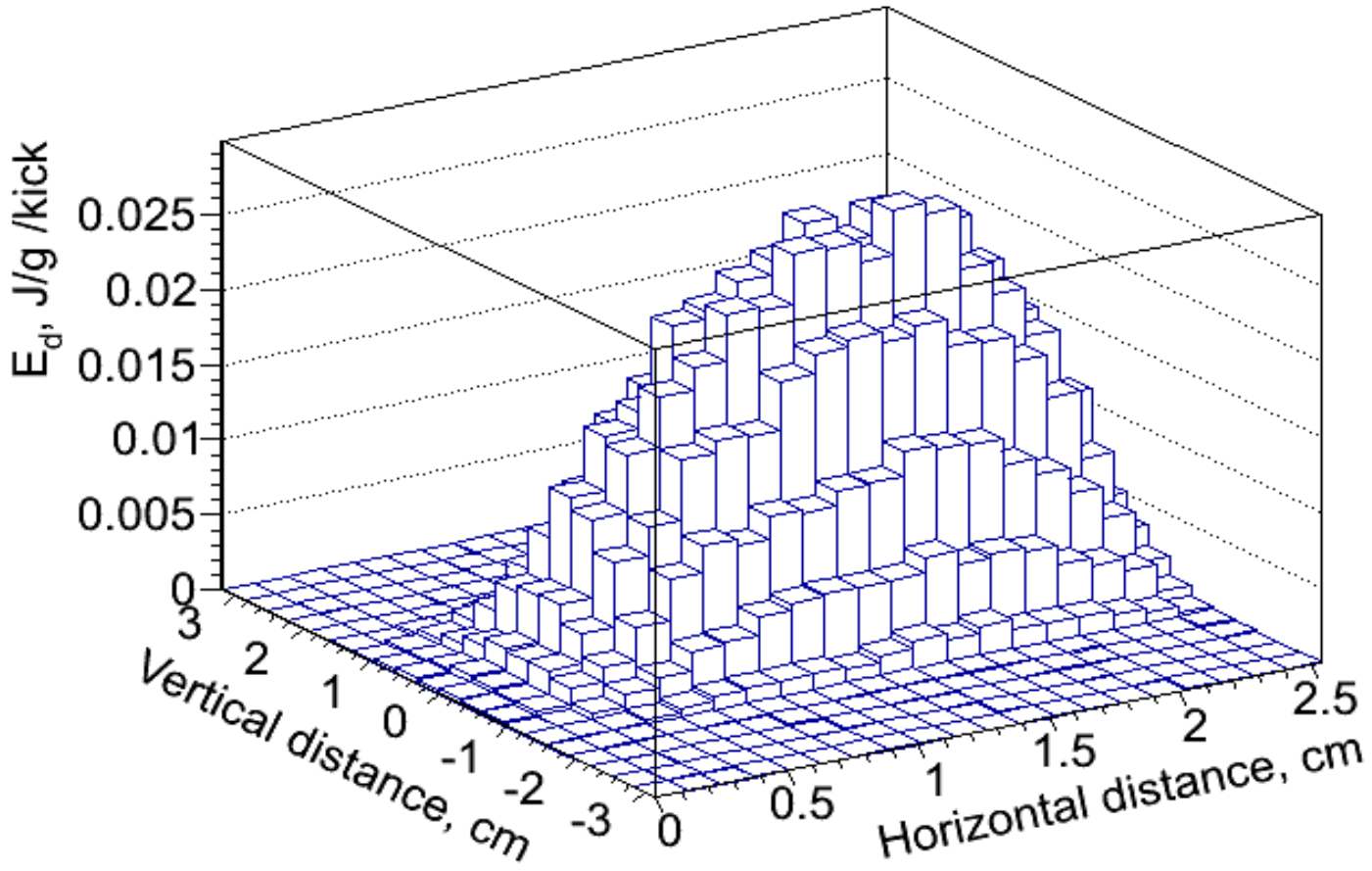

LONG
13
BMA013
Wt: 500 lbs
50-100
1 HOUR MAX.


30”
30”
12’-3 ”
96”
24”
18 -11 ”
75”
10 ‘
All Measurements Approximate

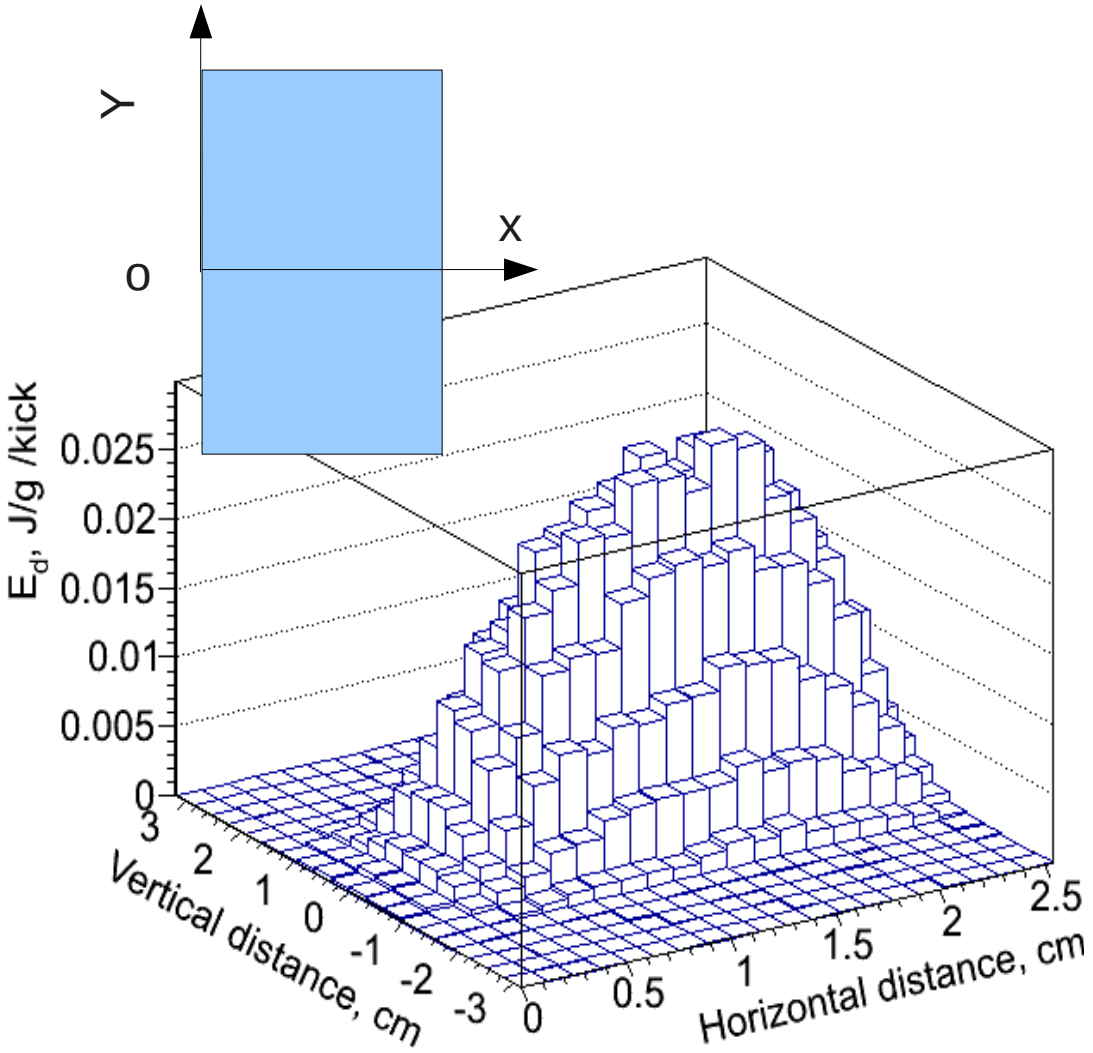


The wall thickness of the tunnel (Section A-A) is 14“, floor - 16". Sections B-B and C-C wall thickness is 16“, and Floor - 18".

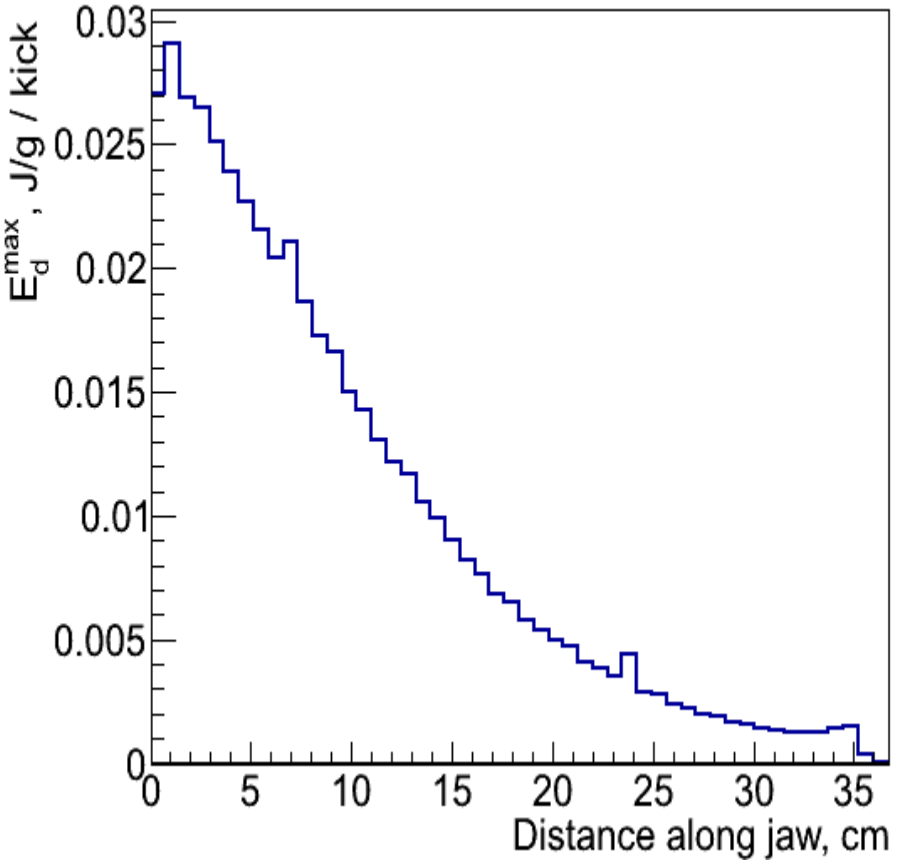
Energy deposition in absorption bar



Energy deposition in absorption bar

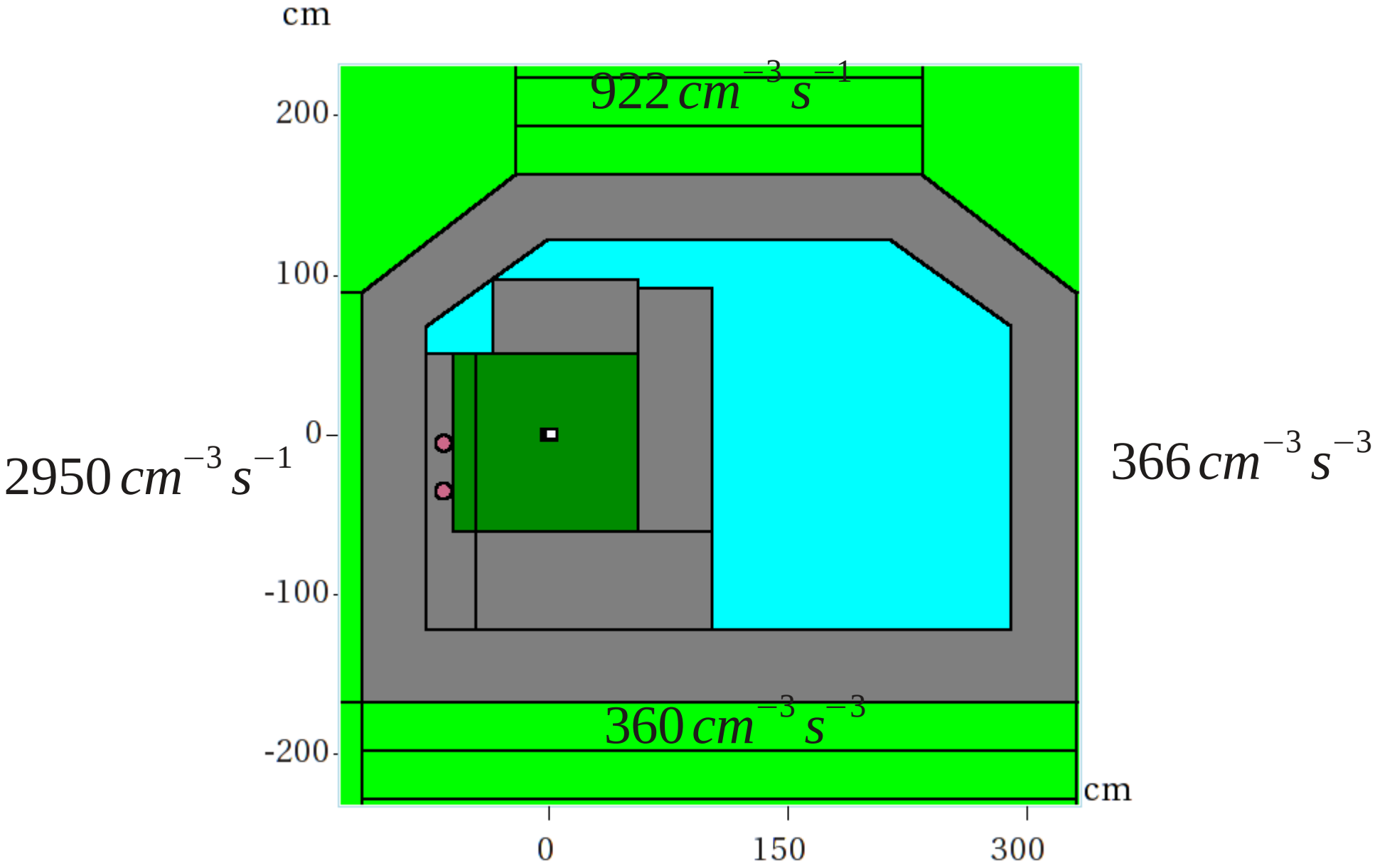


Energy deposition in transverse cross section at the upstream end of bar



Maximum energy deposition in trasverse slice

Sump water: Average star density for 700 MeV beam immediately outside tunnel walls at longitudinal peak:



Conclusions

A.Drozhdin

- **One vertical notcher removes 87% of 3-bunch intensity, with 75% loss at pole tip of Booster magnets, 11% at collimator, and 0.5% on the rest part of the ring.**

- **Using three horizontal notchers at Long-12, is possible to remove 98% at 400MeV and 97% at 700 MeV of 3-bunch intensity to the beam dump located at Long-13 straight section with increased aperture of Short-12 section to R87mm by aperture displacement to dX=20mm.**